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Soil Erosion Risk Assessment Using GIS and ICONA: A Case Study in Kahramanmaras, Turkey

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Abstract: Turkey is one of the countries that have highest rate of soil erosion due to negative topographic structure, soil and climate characteristics along with the problems caused by improper land use practices. Besides other negative effects, soil erosion is the source of sediment that fills reservoirs and thus shortens economic life of dams. Therefore, this study has been carried out on Haman river basin which deposits sediments into Menzelet Dam Lake located in north of Kahramanmaras. In this study, ICONA (Institute for the COnservation of the NAture) model was used to assess soil erosion risk using Geographic Information System (GIS) and Remote Sensing (RS) techniques. ICONA erosion risk map has been derived by overlaying soil erodibility and soil conservation maps. NDVI (Normalized Difference Vegetation Index) values were generated from Landsat 5 TM satellite imagery. According to the results, it was determined that 53.67 % of the study area has very high risk, 38.1 % of the area has high risk, 6.94 % of the area has medium risk, 1.17 % of the area has low risk, and 0.12 % of the area has very low risk of soil erosion.

Keywords: ICONA, land use, NDVI, soil erosion, topography

ICONA ve GIS Kullanılarak Erozyon Riskinin Değerlendirilmesi: Kahramanmaraş Örneği, Türkiye

Öz: Türkiye, hatalı arazi kullanımından kaynaklanan sorunlarla birlikte olumsuz topoğrafik yapı, toprak ve iklim özellikleri nedeniyle dünyada en çok toprak erozyonuna uğrayan ülkelerden biridir. Toprak erozyonu oluşturduğu pek çok olumsuz sonuçların yanında özellikle barajların dolmasına ve ekonomik ömürlerini öngörülenden daha kısa sürede tamamlamalarına neden olmaktadır. Bu nedenle, araştırma Kahramanmaraş ilinin kuzeyinde yer alan ve Menzelet Barajına sediment taşıyan Haman Deresi yağış havzasında gerçekleştirilmiştir. Araştırmada uzaktan algılama ve coğrafi bilgi sitemleri teknikleri kullanılarak ICONA (Institute for the COnservation of the NAture) modeli ile erozyon risk analizi yapılmıştır. ICONA Erozyon Risk Haritası, Toprak Erodibilitesi ile Toprak Koruma Haritalarının birbirleriyle çakıştırılması sonucu elde edilmiştir. NDVI (Normalized Difference Vegetation Index) değerleri Landsat 5 TM uydu görüntüsü kullanılarak elde edilmiştir. Araştırmadan elde edilen sonuçlara göre, alanın % 53.67'sinin çok yüksek, % 38.1'inin yüksek, % 6.94'nün orta, % 1.17'sinin düşük ve % 0.12'sinin çok düşük erozyon riskine sahip olduğu tespit edilmiştir.

Anahtar kelimeler: ICONA, arazi kullanımı, NDVI, toprak erozyonu, topoğrafya

1. Introduction

The control of soil erosion processes depends on appropriate land use and management planning. The soil erosion tends to alter physical, chemical and biological properties of soil, due to undesirably interaction among climate, soil, topography, and vegetation (Pla 1997). Besides, the sediment yield due to erosion results in environmental impacts on water quality and aquatic habitat (Akay 2005; Akay et al. 2008). In Turkey, the average altitude is approximately 1250 m and about 60 % of the total land has a slope over 12 %. Because of the topographic conditions, soil erosion is one of the most important environmental problems in Turkey since approximately 73% of the land is subject to severe and very severe soil erosion (Doğan 1998). In Turkey, over 345 million tons of sediment was carried into the rivers, lakes, dams, and seas per year (GDREC 2008). Dams that have a life-span of 100 years approximately due to soil erosion are usually filled with sediments before the end of their planned economical life. As an example, Çubuk I Dam lost 70 % of its storage capacity in 54 years, Seyhan Dam lost 40 % of its storage capacity in 37 years, and Kartalkaya Dam lost 30 % of its storage capacity in 25 years due to sediment accumulation in the reservoirs. The economic life of these dams will be around 50-60 years as long as current erosion and sedimentation process continues. Sustainable management and conservation activities are crucial in dam watersheds for natural resources and national economy.

According to the ICONA report (1991), approximately 20% of the agricultural lands of European Union (EU) countries had high or very high water erosion vulnerability. It is estimated that 51% of the agricultural areas of EU countries will face serious human-induced land degradation and increasing soil erosion problems by 2050 based on prevailing soil erosion rates. Fast and reliable sediment yield and runoff prediction in Turkish watersheds are very important in terms of planning and implementation of soil conservation techniques (Yuksel et al. 2007a). There have been several models developed to estimate soil loss, runoff and erosion risks such as RUSLE (Revised Universal Soil Loss Equation), EPIC (Erosion Productivity Impact Calculator), ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation), ICONA (Institute for the COnservation of the NAture), WEPP (Water Erosion Prediction Project), and CORINE (COoRdination of INformation on the Environmet)
(Wischmeier 1976; Beasley et al. 1980; Bayramin et al. 2003; Flanagan et al. 1995; CORINE 1992).

USLE (Universal Soil Loss Equation) is one of widely used mathematical models that estimate the amount of soil loss by erosion. The equation was developed by Wischmeier and his friends in 1971 to be used in agricultural areas and then construction sites and rangelands with forests were included to the model in 1971 and 1972 respectively. Afterwards, the model were revised in 1987 and renamed as RUSLE (Lal 1994).

EPIC (Erosion Productivity Impact Calculator) model, on the other hand, determines the effects of soil and water resource management on soil fertility and soil erosion. This model requires some parameters such as weather condition, nutrient cycle, plant growth, soil temperature, and environment control of plants during simulation (Yuksel et al. 2007b).

ANSWERS (Areal Nonpoint Source Watershed Environment Response Simulation) is a hydrological model which is generally used to determine the method to be applied in order to minimize runoff and sediment yield in agricultural fields (Beasley et al. 1980).

CORINE (COoRdination of INformation on the Environment) is a method employed to determine soil erosion risk (CORINE 1992) designed based on USLE model (Wischmeier 1976) and developed by European Union (EU).

WEPP (Water Erosion Predicting Project) erosion model is a continuous simulation computer program that calculates runoff, soil loss and sediment deposition on a daily basis. WEPP model is capable of predicting spatial and temporal distributions of soil loss in watersheds or hillslopes. Thus, in terms of application, this model can be quite useful to determine areas where soil conservation measures are needed (Okatan et al. 2007).

ICONA (Institute for COnservation of the NAture), developed by Spanish Ministry of Environment (DGCONA), is a soil erosion risk assessment model (Jordan 2000). The soil erosion risk assessment can be determined by using land use/land cover, NDVI, slope, and geologic maps of the area (Bayramin et al. 2003). Haman Creek Basin is located in the eastern part of Menzelet Dam and also forms the downstream of it. As a result of erosion, soil and sediment are transported and deposited to the Menzelet Dam via Haman Creek. This sediment deposition shortens the economic lifespan of the dam due to this high inflow of sediment.

The main purpose of this study was to determine the soil erosion risk in Haman watershed located in the Mediterranean city of Kahramanmaras in Turkey, by using ICONA methodology (ICONA 1997). During the analysis process, the impact of slope, lithofacies, land use and vegetation cover factors on erosion were analyzed separately, in order to evaluate the potential soil erosion risk in the area. The input files for lithofacies, slope, land use and vegetation cover were generated as digital data layers using GIS and RS tools and they are integrated with the ICONA model to produce erosion risk maps.

2. Material and Methods

2.1. Study Area

Study area is located within the Latitudes and Longitudes of 37° 40' 50" - 37° 39' 15" N and 36° 53' 56" - 36° 56' 46" E respectively and 40 km away from Kahramanmaras City Center and covers an area of 1216.34 ha (Figure 1).

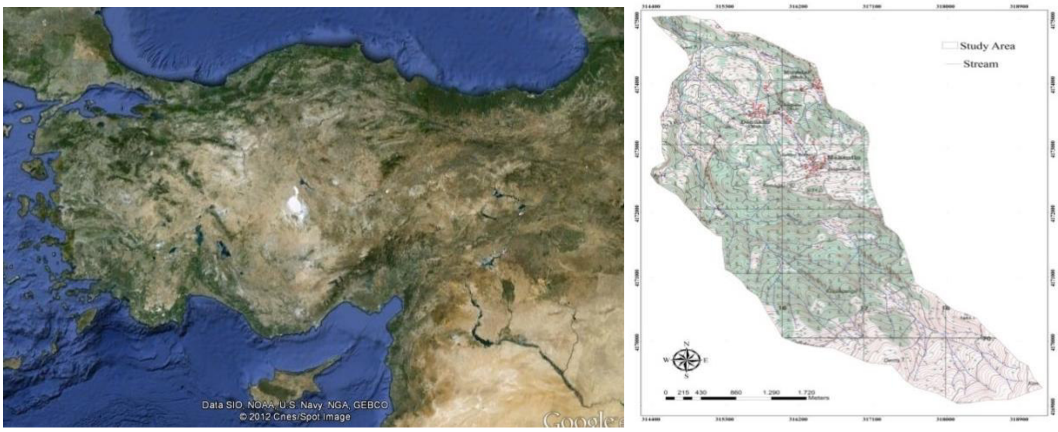

Figure 1: Topographic map and location of the study area over satellite imagery
Şekil 1. *Çalışma alanın topografik haritası ve uydu görüntüsü üzerindeki konumu*

The altitude of the study area ranges between 600 m and 1870 m and slope changes from 0 % to 34 %. Annual precipitation is above 700 mm and annual mean, maximum and minimum temperatures are 16.7 °C, 45.2 °C and -9.6 °C respectively (DMI 2010). The study area is dominated by forest ecosystems, bare land, shrubs, grassland and agricultural land. C2B3’s2a’ equation was found by Thornthwaite method (Thornthwaite, 1948). According to this, the study area is classified as semi-humid medium temperate climate zone which results in large deficit of water throughout summer. Active surface erosion is observed in the study area.

In this study, DEM, satellite imagery and digital geologic maps are employed in order to determine erosion risk maps using ICONA model. 1/25000 scale digital geologic maps developed by General Directorate of Mineral Research and Exploration in Turkey were used to determine geological characteristics of the study area. Slope map of the study area was created from DEM in ArcGIS. Landsat 5 TM satellite imagery acquired in 20 August 2011 was used to determine vegetation characteristics of the area with Raster Calculator tool in ArcGIS. Furthermore, land use/land cover map of the study area was generated from satellite imagery by employing supervised classification technique in Erdas Imagine 9.1.

The predictive phase of the study mainly consists of data processing with 7 different steps as illustrated in Figure 2 below.

Step 1) Generating slope map: Slope map was produced from DEM and categorized into 5 classes (1- Flat to gentle slopes (0-3 %), 2- Moderate slope (3-12 %), 3- Steep slope (12-20%), 4- Very steep (20-35%), 5- Extreme slope (>35%)).

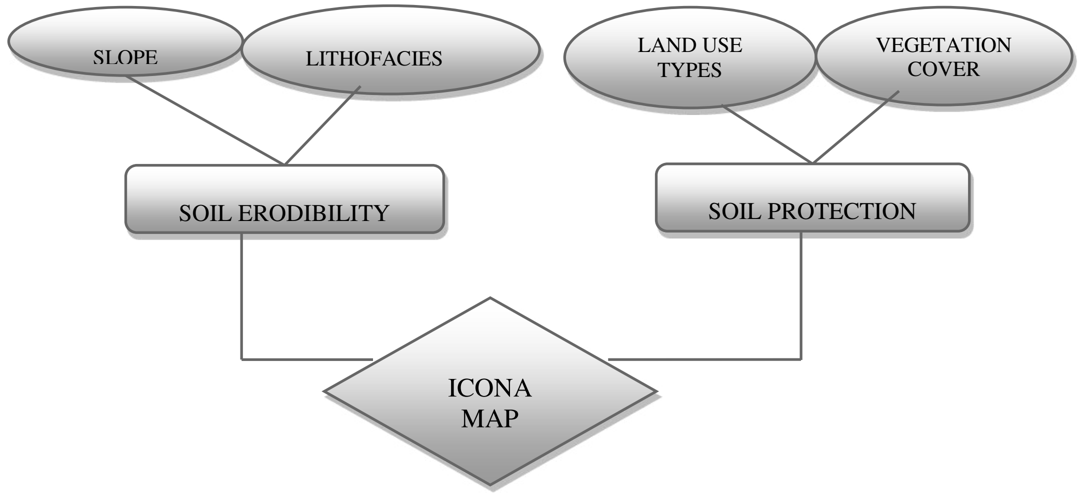

Figure 2. Flow diagram of the ICONA model
Şekil 2. *ICONA modelinin akış diyagramı*

Step 2) Preparing lithofacies map: Lithofacies layer was generated with the help of digital geologic maps and categorized into 5 groups based on geologic formations as shown in Table 1, but since there are no materials of b and c in the study area, materials a, d and e were used.

Table 1. Lithofacies classes
Çizelge 1. *Litofasiyes sınıfları*

Lithofacies classes	Type of material
(a)	Non-weathered compact rock, strongly cemented conglomerates or soils, crusts, hard pans outcrops (massive limestone, highly stony soils, igneous or eruptive rocks, locally crusted soils).
(b)	Fractured and/or medium weathered cohesive rocks or soils.
(c)	Slightly to medium compacted sedimentary rocks (slates, schists, compacted marls, etc.) and/or soils.
(d)	Soft/low-resistant or strongly/deeply weathered rocks (marls, gypsum, clayey slates, etc.) and/or soils.
(e)	Loose, non-cohesive sediments/soils and detritic materials.

Step 3) Creating erodibility map: Erodibility map was created by overlaying the slope map on top of the lithofacies map. The polygons resulting from the overlaying of the two reference maps were classified according to the following matrix shown in Table 2. Erodibility map was classified into 5 groups (1. Low (EN), 2. Moderate (EB), 3. Medium (EM), 4. High (EA), 5. Extreme (EX).

Steps 4 and 5) Generating land use/land cover and vegetation cover maps: In steps 4 and 5 NDVI calculated from atmospherically and topographically corrected satellite imageries was employed in order to determine vegetation structure and closure. NDVI is formulated as follows:

NDVI= (Band 4 – Band 3) / (Band 4 + Band 3) (Erdas 2002). In the equation above, Band 4 and Band 3 represent NIR and RED bands respectively. Landsat image was rectified using 1/25000 scaled topographic image nearest neighbor technique with UTM European Datum 1950 (Türker and Gacemer 2004). The rectification error was found to be 0.35. Geometric correction is done because of the difference image rotation occurred due to elevation (Baydemir 2008). The image was classified using supervised classification technique in Erdas Imagine 9.1. Land use is categorized into six classes according to ICONA method: 1) Dry farming (herbaceous), 2) Ligneous crops (olive, almonds, fruit trees, and vineyards), 3) Irrigation, 4) Forest, 5) Shrub land, 6) Rangeland, but it was determined that there was no irrigated agricultural land and shrub land (class 3 and class 5) in the study area.

Table 2. Slope and lithofacies matrix
Çizelge 2. *Eğim ve litofasiyes matrisi*

Slope Classes	**Lithofacies classes**				
	1(a)	2(b)	3(c)	4(d)	5(e)
1.	1(EN)	1(EN)	1(EN)	1(EN)	2(EB)
2.	1(EN)	1(EN)	2(EB)	3(EM)	3(EM)
3.	2(EB)	2(EB)	3(EM)	4(EA)	4(EA)
4.	3(EM)	3(EM)	4(EA)	5(EX)	5(EX)
5.	4(EA)	4(EA)	5(EX)	5(EX)	5(EX)

Vegetation cover was also classified into four groups: 1) 25 % or less, 2) 25 %-50 %, 3) 50 % - 75 % and 4) 75 % or more but it was found that first two groups of vegetation cover were found in the study area belongs to first two groups.

Step 6) Creating soil protection map: In this step, soil protection map was retrieved by overlaying vegetation cover map and land use map using ArcGIS 10. By using this map, land use and vegetation cover matrix was created as illustrated in Table 3 below.

Table 3. Land use and vegetation cover matrix
Çizelge 3.*Arazi kullanım ve bitki örtüsü matrisi*

Land Use	**Vegetation Cover**			
	1	**2**	**3**	**4**
1	5(MB)	5(MB)	4(B)	4(B)
2	5(MB)	5(MB)	4(B)	3(M)
3	3(M)	2(A)	1(MA)	1(MA)
4	4(B)	3(M)	2(A)	1(MA)
5	5(MB)	4(B)	3(M)	2(A)
6	5(MB)	4(B)	3(M)	2(A)

Soil protection map was categorized into five groups: 1) Very high (MA), 2) High (A), 3) Medium (M), 4) Low (B), 5) Very low (MB).

Step 7) Creating ICONA erosion risk evaluation map: The ICONA erosion risk evaluation map was created by overlaying soil erodibility map and soil protection map and then it was classified into 5 groups according to erosion risk status: 1) Very low, 2) Low, 3) Moderate, 4) High, 5) Very high.

Finally, erosion status matrix of the study area was created by using erodibility map and soil protection map as shown in Table 4 below.

Table 4. Erosion status matrix
Çizelge 4. *Erozyon durum matrisi*

Level of soil Level of erodibility	Level of soil Level of erodibility				
	1(EN)	**2(EB)**	**3(EM)**	**4(EA)**	**5(EX)**
1(MA)	1	1	1	2	2
2(A)	1	1	2	3	4
3(M)	1	2	3	4	4
4(B)	2	3	3	5	5
5(MB)	2	3	4	5	5

3. Results and Discussion

Slope, one of topographic elements, plays an important role in watershed management not only for hydrologically but also for water erosion. Mean slope of watershed is a key parameter for runoff and peak and shape of hydrograph that belongs to stream flow. According to the slope map, which was created from DEM, 88.17 % of the study area contains very steep and extreme slope classes (See Figure 3 and Table 5).

This rough topography increases erosion and sedimentation problems altogether. The relationship between erosion intensity and slope differs under diverse precipitation characteristics and land use conditions.

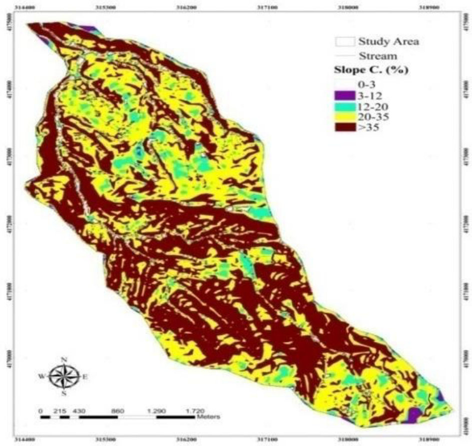

Figure 3. Slope map of the study area
Şekil 3. *Çalışma alanın eğim haritası*

Table 5. Slope classes by areal percentage in the study area
Çizelge 5. *Çalışma alanının erozyon sınıfları alansal dağılımı*

Slope Classes		Area(ha)	Percent (%)
Flat and gentle	0-3 %	15.00	1.23
Moderate	3-12 %	29.56	2.43
Steep	12- 20%	99.34	8.17
Very Steep	20-35 %	478.86	39.36
Extreme	> 35 %	593.58	48.81
TOTAL		**1216.34**	**100**

For example, it was determined that when slope increases from 5 % to 10 %, erosion amount increases 3 times but when slope goes up to 15 %, erosion increases 5 times (Balcı and Ökten 1987). The steep ground slope potentially accelerates the surface runoff which dramatically increases erosion (Lal 1994). Previous studies indicated that the erosion intensity may increase by 2.3 to 3.5 times when slope increases from 8 % to 45 % under the same percentage of vegetation cover (Dinzhong 1996). As Millward and Mersey (1999) explained, soil erosion has accelerated due to limited land resources for agricultural practices, and the more continuous use of steeper lands for agriculture.

Due to intense and incorrect land use in the watershed, vegetation cover was destroyed tremendously and in the meantime soils became extremely vulnerable to erosion.

Lithofacies map was produced with the help of geological map of the study area as illustrated in Figure 4.

It shows physical properties such as color, texture, and sedimentary structure of rocks. More than half of the study area consists of loose, non-cohasive sediment and clastic rocks. As well known, this sediment and bedrockeffect the magnitude of erosion (See Table 6).

Ozel et al. (1999) investigated the erosion risk status of Dalaman Basin by using ICONA erosion model (1997) in Turkey.

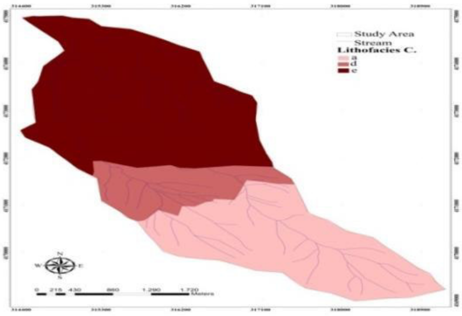

Figure 4. Lithofacies map of the study area
Şekil 4. *Çalışma alanının Litofasiyes haritası*

Table 6. The status of Lithofacies classes of the study area
Çizelge 6. *Çalışma alanının litofasiyes sınıfları durumu*

Litofasiyes Classes	Area (ha)	Percent (%)
(a) Non weathered compact rock, strongly cemented conglomerates or soil, crusts, hard pans outcrops (massive limestone, highly stony soils, igneous or eruptive rocks, locally crusted soils).	421.43	34.64
(d) Soft/low resistant or strongly/deeply weathered rocks (marls, gypsum, clayey slates, etc.) and/or soils.	162.38	13.36
(e) Loose, non-cohesive sediments/soils and detritic materials	632.53	52.00
TOTAL	**1216,34**	**100**

According to the lithopedological properties, the study area consists of loose and sedimentary rocks that are sensitive to soil erosion and have a low resistance to weathering. They reported that the study area has a 17 % low, 23 % moderate and 60 % high level of soil erosion risk.

The soil erodibilty map was produced by overlaying slope and lithofacies maps as illustrated in Figure 5 below.

Results indicate that stream bed and flat areas have low and very low soil erodibility values in the study area. 17.89 % of the study area has very low, low and moderate soil erodibility risk while the rest (82.11 %) has high and very high level of soil erodibilty risk as shown in Table 7 below.

Erodibility matrix that was created with slope and lithofacies is illustrated in Table 8. Due to the fact that more than half of the study area has slightly compact sedimentary rocks, the study area is vulnerable to soil erosion.

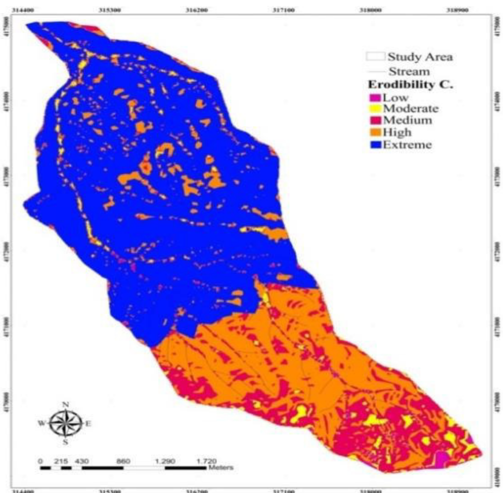

Figure 5. Erodibility map of study area
Şekil 5. *Çalışma alanının erodobilite haritası*

Table 7. The status of soil erodibility classes in the study area
Çizelge 7. *Çalışma alanının toprak erodobilite sınıfları durumu*

Soil Erodobility Classes	Area (ha)	Percent (%)
Low (EN)	12.35	1.01
Moderate (EB)	36.33	2.99
Medium (EM)	168.97	13.89
High (EA)	304.84	25.07
Extreme (EX)	693.85	57.04
TOTAL	**1216,34**	**100**

An accuracy assessment has been carried out to compare classified land use and vegetation cover that were retrieved from Landsat 5 TM satellite imagery with the reference data. For this purpose, 21 points have been determined by using random sample method.

According to classification accuracy, overall accuracy, user's accuracy, producer's accuracy and kappa were found to be 85.71 %, 82.95 %, 80.83 %, and 0.79 respectively. Results indicate that forest has the largest area coverage with 47.37 %, on the other hand, orchards occupy the least area with 2.47 % in the study area as illustrated in Figure 6 and Table 9 below.

Table 8. Erodobilite matriks
Çizelge 8. *Erodobilite matrisi*

Slope Class	Lithofacies Class				
	1(a)	**2(b)**	**3(c)**	**4(d)**	**5(e)**
1	1(EN)	-	-	1(EN)	2(EB)
2	1(EN)	-	-	3(EM)	3(EM)
3	2(EB)	-	-	4(EA)	4(EA)
4	3(EM)	-	-	5(EX)	5(EX)
5	4(EA)	-	-	5(EX)	5(EX)

Table 9. Analysis of land use classes in the study area
Çizelge 9. *Çalışma alanının arazi kullanım dağılımı*

Land Use Classes	Area (ha)	Percent (%)
Dry Farming	380	31.24
Ligneous Crops (olive, almonds, fruit, trees, vineyards)	30	2.47
Forest	576.24	47.37
Range, sparse shrub	230.1	18.92
TOTAL	**1216.34**	**100**

Berney et al. (1997) and Ahlcrona (1988) stated the importance of vegetation cover and its effect on controlling erosion. NDVI layer was classified into two groups: less than 25 % and between 25 % and 50 % in the study area and vegetation cover was derived from that as shown in Table 10.

By looking at this table, it can be seen that more than half of the study area has a canopy closure that is less than 25 %. Karagül (1994) has also investigated erosion tendencies under different landuse soils and found that land use had serious effects on soil erosion.

The reliable land cover data is very important in soil erosion models (Oduro 1996). Therefore, vegetation cover has a crucial importance for the erosion resistance of surface soil (Dingzhong 1996; Tayebi et al. 2016).

As well know, NDVI values vary between -1 and +1. In NDVI calculation NIR and RED bands are used since healthy vegetation reflects more in NIR band than RED band. According to NDVI calculation, values were found to be between 0.2 and 0.8 in the study area as seen in Figure 7 below.

Soil protection map, shown in Figure 8, was created by overlaying land use and vegetation cover maps. Soil protection matrix that was created with land use and vegetation cover is illustrated in Table 11. According to soil protection map, 17.72 % and 50.85 % of the study area has very low/low and moderate soil protection values, respectively as illustrated in Table 12.

Even though 47.37 % of the study area is classified as forest, the canopy closure in forest is found to be very low. Land use and vegetation cover play an important role in soil erosion studies.

Vegetation cover lessens the impact of raindrops before they hit the soil, reducing the soil's ability to erode. Soil erosion potential increases with the lack of vegetation cover (Wall2003).

Table 10. Analysis of vegetation covers in the study area

***Çizelge 10.** Çalışma alanının bitki örtüsü dağılımı*

Vegatation Cover Coverage	Area (ha)	Percent (%)
Less than 25 %	621.72	51.11
25-50 %	594.62	48.89
TOTAL	**1216.34**	**100**

Figure 6. Land use map of the study area

***Şekil 6.** Çalışma alanının arazi kullanım haritası*

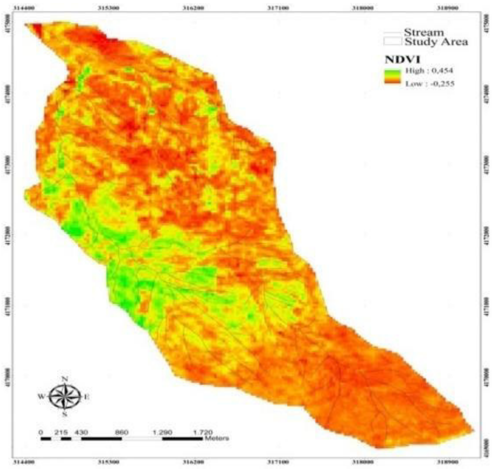

Figure 7. NDVI map of the study area

***Şekil 7.** Çalışma alanının NDVI haritası*

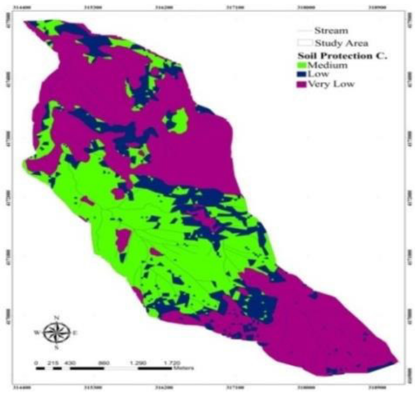

Figure 8. Soil protection map of the study are

***Şekil 8.** Çalışma alanının toprak koruma haritası*

Table 11. Soil protection matrix
Çizelge 11. *Toprak koruma matrisi*

Land Use	Vegetation Cover			
	1	**2**	**3**	**4**
1(AH)	**5(MB)**	**5(MB)**	-	-
2(AA)	**5(MB)**	**5(MB)**	-	-
3(AR)	-	-	-	-
4(FA)	**4(B)**	**3(M)**	-	-
5(FM)	-		-	-
6(FX)	**5(MB)**	**4(B)**	-	-

Table 12. Soil protection values of the study area
Çizelge 12. *Çalışma alanının toprak koruma değerlerinin alansal dağılımı*

Soil Protection Classes	Area (ha)	Percent (%)
Medium (M)	382.32	31.43
Low (B)	215.55	17.72
Very Low (MB)	618.47	50.85
TOTAL	**1216.34**	**100**

Having vegetation cover of 25 % or less in the study area increases the risk of erosion. The current ICONA erosion risk map was created by overlaying soil erodibility and soil protection maps as shown in Figure 9 and the matrix used was also illustrated in Table 13.

According to these results, it was found that 91.77 % of the study area has very high and high erosion risk, while 1.29 % of the study area was found to be very low erosion risk. The susceptibility of Mediterranean ecosystems to soil erosion was indicated by Berney et al. (1997). Similar views stating that semi-arid regions have higher erosion problems were also presented by the ICONA report (1991) and RIVM's data (2000).

Table 13. ICONA erosion matrix
Çizelge 13. *ICONA erozyon risk matrisi*

Level of Soil Protection	Level of Erodibility				
	1(EN)	2(EB)	3(EM)	4(EA)	5(EX)
1(MA)	-	-	-	-	-
2(A)	-	-	-	-	
3(M)	**1**	**2**	**3**	**4**	**4**
4(B)	**2**	**3**	**3**	**5**	**5**
5(MB)	**2**	**3**	**4**	**5**	**5**

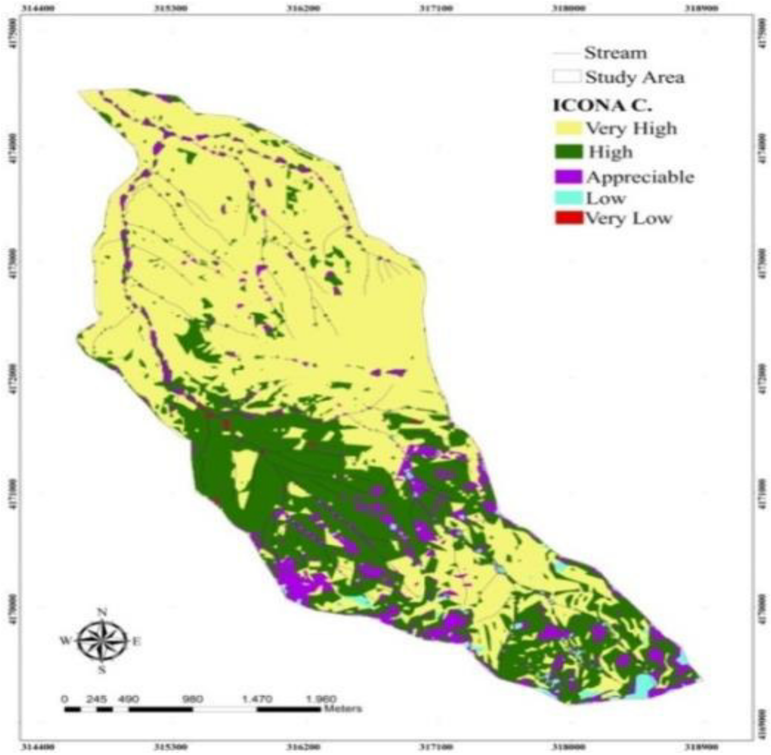

Figure 9. ICONA Erosion Risk map of the study area
Şekil 9. *Çalışma alanının ICONA erozyon risk haritası*

4. Conclusions

In this study, the high risk of erosion appears to be the most in highly sloped, rough areas, rangelands and bare lands. Due to the overgrazing of rangelands, soils are exposed to erosion more often thus rangelands must be managed carefully. Soil erosion is generally influenced by a considerable number of factors including vegetation cover, land use, bedrock, topography, and climate.

Fertile soils in the study area have been carried by streams to the Menzelet dam. Thus, areas that are steep, rough and located near the streams possess high risk for erosion due to sediment deposition right from top to bottom. As a result, ICONA model that was developed using GIS and RS techniques is found to be very effective and useful to derive erosion risk maps. Model provides the information of areas to manage the high risk of erosion potential. Therefore, watershed managers can locate the problematic areas in the watershed and implement necessary precaution measures to minimize or prevent erosion.

In the higher parts of the watershed, VII. Class lands that are allocated for forest and rangeland should not be used for agricultural purposes and soil loss caused by erosion should be prevented by afforesting these lands. Since the study area is located in dam watershed, land classification must be followed to prevent economic lifespan of the dam. Furthermore, afforestation should be undertaken in the forest areas as soon as possible but priority should be given to broadleaf species. Because broadleaf trees lose their leaves in winter, water loss declines to minimum through interception and water consumption drops to almost zero through transpiration. In addition to afforestation efforts, herbaceous plants, which protect soil with their roots may also be used in the study area.

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